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PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Tomographic Radioactivity Scanner with Simultaneous Readout of Several Planes

I, HAL OSCAR ANGER, a resident and citizen of the United States of America, 1771 Highland Place, Berkeley, California 94709, County of Alameda, State of California, United States of America, do hereby declare the inventtion, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement: —

Background of the Invention

This invention relates to detectors for imaging the distribution of radioactivity and more particularly to detectors for simultaneously obtaining multiple images focussed at different planes or levels in a subject. The invention described herein was made in the course of, or under, Contract W-7405-eng-48 with the Atomic Energy Commission of the United States of America.

In a typical usage of a radiation detector, a radioactive substance is introduced into a subject, such as a medical patient, to locate any areas where such substance concentrates or to trace the flow of the substance through some portion of the subject. Some conventional radioactivity imaging devices provide a single image focused at a single plane in the subject. Since the depth of a radiation source in the subject is generally unknown, several repositionings of the imaging device may be necessary before a sharply focused image is obtained.

Even if a focused image is obtained the spatial configuration of the radiation source in the subject cannot be determined.

Summary of the Invention

In the present apparatus, a plurality of readcut pictures is simultaneously obtained, each of the pictures being focused at a different plane in the subject. To obtain multiple readouts, a radiation image detector having a collimator is placed adjacent a subject and relative motions between the collimator and the subject are induced. The relative motion causes radiation images of radiation sources in the subject to move over a scintillator in the image detector. The speed and the extent of the movement of the images on the scintillator is related to the depth of the source in the subject. The radiation images on, and more particularly the scintillations in the scintillator are then transformed into output signals. The output signals are adjusted and combined with output signals defining the coordinate position of the radiation image detector so that radiation distribution records focused in different planes are obtained and recorded, such as on photographic film or in a computor device.

It is an object of the present invention to provide an improved means for accurately displaying the position of radioactive material in a selected plane of the subject.

It is another object of the present invention to simultaneously obtain multiple images of radioactive material in a subject, each image being focused at a differing plane therein.

Brief Description of the Drawing

The invention will be best understood by reference to the drawing of which:

FIGURE 1 is a general view of the scanner with electronic circuitry indicated in block form,

FIGURE 2 is a section view taken at line 2—2 in FIGURE 1,

FIGURE 3 is a partial section view of an image probe with radiation sources shown for purposes of explanation,

FIGURE 4 is a schematic view of readout means,

FIGURE 5 shows multiple views of the oscilloscope screen of FIGURE 4 for different positions of the image probe of FIGURE 3,

FIGURE 6 shows the formation of a portion of three readouts for point sources on three different planes of FIGURE 3, and

FIGURE 7 shows five complete readouts, of sources of FIGURE 3, each focused at different planes.

Description of the Preferred Embodiment

Several image detectors suitable for use in the present invention are described in detail in The Transactions of the Instrument Society of America, Vol. 5, No. 4, pages 311—334, October 1966. The embodiment of the invention described here utilizes an image detector similar to that shown on pages 313, 314 and 328 of the above reference and described in U.S. No. 3,011,057, issued November 28, 1961, for "Radiation Image Device".

FIGURE 3 shows a broken-out view of such an image detector 43 which has a thick scintillation crystal 61 disposed inside an outer radiation shielding casing 62 and viewed by an array of phototubes 65. Radiation falling on the scintillation crystal 61 produces a flash of light in the crystal, generating a signal in each phototube 65 with an amplitude varying according to the distance between the scintillation and the phototube.

Generally speaking, a collimator having a multitude of small openings is placed adjacent the scintillation crystal intermediate the crystal and the subject containing the radiation source. Radiation from a source passes through the collimator to produce radiation images on the light flashes in the scintillation crystal. The size of the radiation images from a source, say a point source, vary as a function of the distance between the source and the focal plane of the collimator and, therefore, the distance between the collimator and the source.

During the relative motion between the collimator and the source the radiation image moves over the scintillation crystal at a rate which also varies as a function of the distance between the the collimator and the plane in which the source lies. The moving radiation image causes light flashes to appear in different parts of the scintillation crystal, the scintillations are picked up by the phototubes, and are transformed into electric output signals defining the position of the scintillations on the crystal. The output signals are adjusted, combined with signals indicating the coordinate position of the image detector, and recorded in such a manner that the record of readout provides focused images of radiation sources in a number of different planes in the subject.

Referring again to FIGURE 3, the focused collimator 63 has a plurality of thin coaxial shields each defining a thin truncated cone with apices lying on a common point 64. The point 64 at which such apices lie is the focal point for the collimator and radiation from a radioactive point source 66 disposed at such focal point can pass between all of the shields in the collimator and cause scintillations or flashes of light over the full area of crystal 61. As previously discussed, scintillations in the crystal 61 are viewed by phototubes 65 which each produce resulting output signals having an amplitude corresponding to the distance from the scintillation to the light sensing surface of the phototubes. The output signals are coupled to an image deriving circuit 44 (shown in block form in FIGURE 1) which generates deflection (coordinate) signals corresponding to the position of the individual scintillations on the crystal, and an intensity (brightness) signal. The image deriving circuit uses known circuitry and its output signals are applied to a cathode-ray oscilloscope 46 (shown in FIGURE 4). Utilizing such signals, light flashes are caused to appear on the oscilloscope screen at positions corresponding to the positions of the individual scintillations in crystal 61.

Other radiation sources such as a point source 67 disposed in a plane A between the focal plane and the collimator, and a point source 68 disposed on a plane E beyond the focal plane are present. Radiation from these sources can only pass through one or a few of the openings in the collimator and, therefore, produces images and light flashes extending over a smaller area of the scintillation crystal. The source 66 is intermediately disposed on a focal plane C while intermediate planes B and D are indicated for future reference.

A special lens system in a light shield 47 (shown in FIGURE 1) projects images appearing on the screen of the oscilloscope 46 onto a photographic film within a second light shield 48 as more fully described hereinafter.

Referring now to FIGURES 1 and 2, a means 10 is provided to move the collimator in a preferably rectilinear manner relative to the radiation source. General considerations of rectilinear scanning are described on pages 381 to 426 of the text Instrumentation in Nuclear Medicine by Gerald J. Hine, published by Academic Press, New York, 1967. Means 10 includes a stationary platform or table 11 with supports 12, there being sufficient clearance under the table for positioning a subject or specimen 13 on support means 14. Usually, only a small portion 16 of the subject is of interest. A lower movable platform 17 is supported upon table 11 on wheels or rollers 18 and

adapted to roll across table 11 in grooves or tracks 19 therein. A motor 21 on table 11, upon closing of power switch 22, pulls the movable platform 17 by winding a line 23 onto a drum 24 driven by motor 21. A normally closed microswitch 26, electrically connected in series with motor 21, automatically stops forward travel of the lower movable platform 17 when operated by tab 27 affixed to the platform.

An upper movable platform 28 is supported on wheels 29 riding in grooves 31 in the top surface of lower movable platform 17, grooves 31 being oriented 90° with respect to grooves 19 in table 11. First and second motors 32 and 33 are alternately energized to draw the upper platform alternately in opposite directions as controlled by a normally-closed limit switch 34 and normally-open limit switch 36 both affixed to lower platform 17. A tab 37 on upper platform operates the limit switches at the desired limits of travel. A relay coil 38 is connected in series with limit switches 34 and 36. When a power switch 39 is closed, motor 33 is energized through relay contact 41, since relay coil 38 is not energized. When limit switch 36 is closed by tab 37, motor 32 is energized through contact 41 and motor 33 is de-energized. Relay coil 38 remains energized through holding contacts 42 until the operation of motor 32 causes tab 37 to open normally closed limit switch 34. The relay is thereby de-energized and motor 33 is again energized.

A pair of position repeating type motors or Selsyn motors 49 and 51 detect motion of the upper and lower platforms respectively, the motors having gear teeth engaging with a rack affixed to such platforms. Electrical output signals indicating the co-ordniate position of the collimator (and the image detector) with respect to substance 13 are thus produced which may be used to remotely repeat the motion of the platforms.

The image detector 43 is mounted on the upper platform 28 and extends downwardly therefrom to view the subject 13. The image detector 43 is moved in a rectilinear scan pattern across the portion 16 of subject 13. To provide such scan, motor 21 is caused to move the lower platform very slowly with respect to the back-and-forth motion of the upper platform 28.

Referring now to FIGURE 4, there is shown the readout means 45 with the light covers 47 and 48 removed. An arrow 72 is indicated on the screen 71 of a cathode-ray-tube in the oscilloscope 46 to aid in indicating the various optical characterisitics of the readout means. However, such arrow 72 is not intended to be an example of a display as obtained in the operation of the present invention since only single points of light occur momentarily throughout the screen 71.

A photographic film 73 is affixed to an upper movable table 74 supported by guides 76 at opposite ends of the table, the guides fitting into grooves 77 in the ends of table 74. A selsyn repeater motor 78 receives the output signals from selsyn motor 49 of FIGURE 1 and drives a gear wheel 79 which engages a rack 81 on table 74, causing the table to move in synchronism with upper platform 28 of FIGURE 1. Motor 78 and guides 76 are affixed to a lower table 82 which is in turn transversely moved by the same means as the upper table 74. Guides 83 fit into grooves 84 in the lower table which is driven by a repeater selsyn motor 86 through gear wheel 87 and rack 88. Motor 86 follows the motor 51 of FIGURE 1, whereby film 73 moves in synchronism with image detector 43. The rate of movement of the film may, of course, differ from that of the image detector and may be more or less as is most practical.

Film 73 is divided into a number of fields 73a through 73e which corresponds to the number of different planes read out by the apparatus. In a presently preferred embodiment 5 planes are read out so that there are 5 fields 73a through 73e on the film. Each field corresponds to the full area scanned by image detector 43.

Images of the screen 71 are projected onto film 73 by lenses of different focal lengths to obtain focused radiation distribution records of the five planes in the subject. The five records show the position of the radiation sources in the form of high resolution readouts. The planes are chosen so that they cover the full depth of the subject and the radiation records provide a picture of the distribution of radiation sources throughout the subject.

A lens 89 is disposed between screen 71 and film 73 and provides a relatively large image of the screen 71 on field 73a. A lens 91 is also disposed between screen 71 and film 73 and provides a smaller image of the screen 71 on field 73b of the film. A plate 92 is disposed near the film and has an aperture 93 through which light from screen 71 can fall on field 73c. An inverting prism 94 and a lens 96 combination and an inverting prism 97 and lens 98 combination each provide progressively larger images of screen 71 on fields 73d and 73a, respectively, the images being inverted with respect to the images from lenses 89 and 91. Lenses 89, 91 aperture plate 92, lenses 96 and 98 are also respectively denoted by letters A to E to indicate which lens provides an image focused at the correspondingly identified planes A to E in FIGURE 3. It will be obvious that light shielding

should be provided to prevent extraneous light from reaching the film 73.

The readout process is considered in detail with regard to FIGURES 5 to 7. To simplify the explanation, the scanning motion is shown as advancing transversely across the scanning region, rather than with a slightly skewed scan that would be obtained with the apparatus shown in FIGURES 1 and 2. If desired a transverse scan could be obtained with slight modification of the apparatus of FIGURES 1 and 2.

FIGURE 5 shows the light flashes on screen 71 of the oscilloscope as screen images 67a through 67e, 68a through 68e and 101 during five scans of image detector 43 past sources 67, 66, and 68 located on planes A, C, and E of FIGURE 3. An image of source 67 located, for example, two centimeters from the collimator on plane A of FIGURE 3, appears on scintillation crystal 61 and, therefore, also on the screen in the form of screen images 67a, during the first scan line. Screen image 67a appears on the bottom portion of the screen and moves across the screen in the opposite direction to the scanning direction. After screen image 67a disappears screen image 68a of source 68 appears on screen 71 in the same manner. Since source 68 is beyond the focal plane C screen image 68a appears on the top portion of the screen and moves across the screen in the same direction as the scanning direction. During the next scan screen image 68b appears first, then followed by screen image 67b. It will be noted that the screen images move toward the center of the screen and then toward the other side during the successive scans past the radiation sources. The closer a radiation source is to the focal plane, the larger is the radiation image on scintillation crystal 61 and the screen image on screen 71, and the faster move the images across the crystal and he screen. Thus, screen image 101 from source 66, located, for example, eight centimeters from the collimator on Plane C at the geometric focal plane, appears only briefly on the screen since the response zone is narrowest at the focal plane.

FIGURE 5, therefore, illustrates the screen images during five scans past the sources shown in FIGURE 3. Each of the images 67a through 67e and 68a through 68e, of course, moves continuously and evenly across the screen from the moment of their first appearance thereon until they disappear. As image detector 43 scans the source 67 (see figures 3 and 5) the radiation from the source passes only through passages in one side of collimator 63 thus directing radiation only to one side of crystal 61 and causing the appearance of screen images 67a. As the detector 43 continues to move past source 67 during subsequent scans, radiation passes through the passages at the center of the collimator to result in screen images 67c and then through passages at the opposite side of the collimator to cause screen images 67d and 67e. When source 66 is positioned at the focal point 64 of the collimator 63, radiation therefrom can pass through all of the collimator passages. Screen image 101 obtained when the image detector 43 is directed at the source 66 is spread completely over, therefore, covers all of screen 71.

It should be remembered that film 73 moves in synchronism with detector 43 so that the x—y position of the detector relative to subject 13 is the same as the x—y position of the film with respect to the screen 71. The latter, however, is preferably on a reduced scale so that radiation records of a relatively large subject, such as a human head, for example, is read out on a relatively small film. From the set of oscilloscope displays shown, several planes can be read out in sharp detail by means of the lenses and aperture plate of FIGURE 4.

First, consider the readout of plane C. Aperture plate 92 is placed almost in contact with field 73c of the photographic film and remains stationary or fixed with respect to the oscilloscope. If a radiation source appears at the focal point of the collimator a fully illuminated screen 71 (screen image 101) exposes the film through the aperture and results in a high resolution exposure due to the high light intensity and short duration of the flash. Screen images from radiation sources in other planes result in low resolution, blurred exposures of the film in field 73e through the aperture in plate 92 because such images, as for example, any of the images 67a through 67e, remain on the screen for relatively long periods of time. Thus, only film exposures from sources in the focal plane of the collimator will be clear and sharp.

FIGURE 6 provides a graphic illustration of a scintiscan readout of sources shown in FIGURE 3 as produced by lens 89, lens 98 and aperture plate 92. The uppermost portion of FIGURE 6 illustrates the size and relative position of the light flashes on the scintillation crystal, or of screen images 67c, 68c and 101 on oscilloscope screen 71 during the third scanning line illustrated in FIGURE 5 where image detector 43 passes directly over sources 66, 67 and 68.

The readout of radiation sources in plane A which, for example, may be two centimeters from the collimator, is first considered. As the image detector 43 scans across source 67, screen image 67c moves over screen 71 from right to left. Screen image 67c is projected on field 73a of photographic film 73 by lens 89. The film 73

moves in the same direction and with the same speed as the screen image 67c projected on the film by lens 89 so that all screen images 67c are recorded on the same area of film. Thus, source 67 is read out on the film with sharp resolution.

Only one scan line is shown in FIGURE 6, but source 67 also causes screen images 67a, 67b, 67d and 67e during other scans past, though not directly over, the source where radiation from that source reaches the scintillation crystal. Although screen images 67a, b, d and e are not centered on screen 71, as is screen image 67c, they are nevertheless superimposed on the same area of field 73a of the film because the transverse displacement of the images on the screen, as shown in FIGURE 5, is duplicated by table 74 and the film. In readout A of FIGURE 6, source 67 is thus sharply resolved, because the movement of the screen images 67a through 67e equals the movement of film 73.

Screen image 101 from source 66, on the other hand, is not sharply resolved in readout 73a, and because screen image 101 covers the entire screen 71, is enlarged by lens 89. Although exposure of the film takes place, it is blurred. Screen images 68a through 68e from source 68 also cause exposure of the film in field 73a but it is likewise not sharply resolved on readout A because its movement over screen 71 does not equal the movement of film. Thus, only screen images 67a through 67e originated by source 67 in plane A result in a sharply resolved picture or readout in field 73a, thereby indicating that a radiation source is located at the plane. The coordinate position of the readout in field 73a of the film is, of course, determined by the position of detector 43 with respect to subject 13 so that the readout accurately shows the position of radiation sources.

In readout 73c, screen image 101 from source 66 is sharply resolved because the aperture in plate 92 is small and scintillations appear on the screen 71 for only a short time, namely when the focused collimator 63 is aimed right at the source 66. Screen images from sources, such as sources 67 and 68, in planes other than in focal plane C, are not sharply resolved in readout C because they appear on the screen for a longer time during the scan. Thus, the exposures of film in field 73c from sources not in the focal plane do not show a high resolution.

In readout 73e, the screen images 68a through 68e are projected on field 73e of the film and are sharply resolved because inverting prism 97 reverse the direction of motion of the screen image on the screen 71. The projected screen images 68a through 68e move with the film, as did images 67a through 67e referred to above. The same area of film in field 73e is exposed as long as screen images 68a through 68e appear on the screen.

If a source is located on plane B, say five centimeters from the collimator, the corresponding screen images move rapidly across the screen than screen images from source 67 in plane A. As referred to earlier, this stems from the fact that the speed with which the scintillations from a radiation source move over crystal 61, and, therefore, the speed with which the screen images move over screen 71, is a function of the distance between collimator 63 and the source. Since the speed of table 74 and film 73 is constant it is necessary to select the focal length of lens 91 so that the screen image projection on field 73b of the film moves at the same speed as table 74 and the film.

Thus, it can be generally observed that the lenses of readout device 45 must be selected as follows: Each lens must have a focal length which causes the projected screen images, resulting from a radiation source in a plane which is to be read out by that lens, to move at the same rate and in the same direction as the film onto which the image is projected. Screen images from all radiation sources in planes other than that particular plane, though projected onto the film, move at different speeds than the film and do not give a sharply resolved picture. In this manner radiation sources in the particular plane can be recorded on the film with high resolution. A read out of several such planes gives a radiation record of several planes of the subject and thereby assures that substantially every part of the subject is sharply resolved in one of the readouts.

For readout of planes D and E, located eleven and fourteen centimeters from the collimator 63, the same sizes of image are used as for planes B and A respectively, but prisms 94 and 97 invert each image. For sources on planes D and E, which are beyond the geometric focus of the collimator, the irradiated area travels in the opposite direction to the apparent motion of the sources. Therefore, inverting prisms 94 and 97 are used for readout of planes D and E to make the reproduced flashes stationary with respect to the moving film.

A graphic representation of five scintiscan readouts of the three soures 66, 67 and 68 on fields 73a through 73e is shown in FIGURE 7. These readouts are composed of many scanning lines necessary to completely image the sources during an actual rectilinear scan, rather than the single line shown as an example in FIGURE 6. Only three highly resolved photographic readouts 66R, 67R and 68R are obtained from the sources. They are located in fields 73c, 73a and

73d, respectively, of the film. Their position in the fields corresponds to the location of the sources in the subject and their appearance on one or the other of the fields of the photographic film determines at which plane, or what depth in the subject, they lie.

Thus, when scanning a subject having radiation sources located throughout, the intensity and spatial position of the sources can be determined. If desired, a greater or lesser number of readouts can, of course, be provided to obtain high resolution images from sources located intermediate the planes shown in FIGURE 3. This requires no more than a corresponding change in the number of lenses and fields on the film. The remainder of the apparatus remains the same.

To read out the activity of a given plane with maximum resolution, a certain relationship must exist between the image detector 43 scanning speed S, the film 73 scanning speed S′, the focused-collimator 63 acceptance angle (total field of view) a, the diameter D of the ocilloscopic image projected on the film 73, the distance f from the focal point to the collimator and, the distance b from the given plane to the collimator. The relationship is:

$$D=2\frac{S'}{S}(f—b)\tan\frac{a}{2}$$

The equation gives the required diameter D of the image projected on the film 73 for maximum resolution of activity laying on a plane located a distance b from the collimator. Without any change in scanning speeds or any other parameter, activity on other planes can be read out with maximum resolution by projecting images of various sizes on the film. The image size is controlled by the placement and focal length of the lens employed. For $b>f$, D is a negative number, and image inversion is required.

When the above parameters are adjusted to obtain maximum resolution of plane A, source 67 in FIGURE 7 is represented by a small intense area whose diameter is equal to that of the irradiated area of the scintillator as projected on the film 73. Source 66 is represented on this readout by an area whose diameter is equal to the screen image diameter D as projected on the film. Source 68 is represented by an area approximately twice as large as the image diameter D. Similar relationships exist in the other scintiscan readouts.

Many variations are possible within the spirit and scope of the invention; for instance, the collimator can be focused at a point off the central axis or at any point forward or aft of the collimator; or it be replaced by a nose cone (not shown) with a pin-hole type aperture. Obviously, differing means could be employed for obtaining the relative motion between the collimator and the subject; and the subject could be moved while the image detector and collimator are stationary. For example, instead of a rectilinear scan the apparatus can be constructed to scan the subject with a straight line, circular or spiral motion. In addition, the display means and/or lenses can be moved while the film is stationary. The particular image detector shown can, of course, be replaced by other types of image detectors known in the art.

In place of the photographic readout system just described, alternate readout sysems can be provided such as one in which the same images are stored in a digital computer device 111 as indicated in FIGURE 1. Then any of the images can subsequently be displayed on a display device 112 for visual inspection, and numerical data can be extracted by conventional techniques. Such display device can be either an oscilloscope or an X—Y type plotter of the type providing an indication on paper with an inking pen at every point for which coordinate information is obtained.

Assuming five complete memory core systems are provided in the computer 111, one core system for each of the planes A to E, the images may be stored as follows. First, x and y signals obtained from the means causing the relative motion between the collimator and the subject, as from motors 49 and 51, indicate the coordinates of the image detector 43 relative to the subject 13. Such x and y signals can, for example, also be obtained by replacing the motors 49 and 51 with potentiometers mechanically coupled to the detector 43 through the gear and rack means described. In a rectilinear scanning apparatus, the origin of this coordinate system is assumed to be located at one corner of the scan. Second, as radiation is detected, a second set of signals, x′ and y′, is produced by the image deriving circuit 44 for each detected radiation as with the previously described readout means. The origin of this second coordinate system is assumed to be located at the center of the scintillator 61 in the image detector 43.

As the detector 43 scans the subject, each scintillation is stored as a single event in each of the five memory core systems in the computer and storage device 111. The storage location is different in each memory system, except for the special case where a scintillation occurs exactly in the center of the scintillator 61, since x′ and y′ are then zero. Prior to being stored, the coordinates of the position of each scintillation

$$X=x+knx', \qquad Y=y+kny'$$

where X=x-coordinate of stored events in a given memory system,

X=y-coordinate of stored events in a given memory system,

k and n=constants whose values determine the distance from the geometric focal plane C of the collimator 63 to the various readout planes A, B, D and E.

For sharp readout of activity on plane C (the geometric focal plane of the focused collimator 63), kn=0. For this readout, the location at which the detected radiation is stored depends solely on the location of the detector 43. For sharp readout of planes A and B, kn is positive, and for planes D and E, kn is negative. The positions of the scintillations within the detector 43 then become relevant, and if the polarity aud magnitude of kn are correct, the movement of irradiated areas across the scintillator 61 exactly compensates for movement of the detector 43. Then planes other than the geometric focal plane are read out in sharp focus.

If k is a constant and n is assigned the values +2, +1, 0, −1, and −2 for planes A to E respectively, an equally-spaced tomographic series of planes will be stored in the five memory systems. Giving kn a negative value is equivalent to inverting the image of the screen 71 with a prism in the photographic readout system previously described, and changing the value of n is equivalent to changing the size of the screen 71 image projected onto the film. When the coordinates from a selected one of the memory core systems in the computer and storage device 111 are applied to the display device 112, an image is obtained as with the photographic means previously described.

As a variation, it is possible to directly store data from the image deriving circuit 44 and motors 49 and 51, and to subsequently perform the calculations described to obtain a readout focused at a desired plane. It should be obvious that there is no restriction as to the number of planes that can be read out and that the various numbers and dimensions used in the above descriptions are merely to provide examples. Therefore, it is not intended to limit the invention except as defined in the following claims. The application of the method herein, in so far as it relates to human subjects is hereby disclaimed.

WHAT I CLAIM IS:—

1. Apparatus for obtaining radio active radiation distribution readout of radiating sources in a subject, said apparatus comprising:

(a) radiation image forming and detecting means for producing images of said sources wherein the position of the image of each source varies with the distance between said means and such source, said means providing a first output defining the position of said images;

(b) means coupled with said detecting means for examining said subject from more than one position and providing a second output defining the position of said detecting means relative the subject; and

(c) means modifying at least one of said outputs and combining said outputs as modified to provide a preferential focusing effect on radiating sources located on a selected plane in the subject.

2. Apparatus as defined in Claim 1, and means for recording said combined outputs.

3. An apparatus as defined in Claim 1 wherein the modifying means provides a plurality of modified sets of at least one of the outputs, and wherein said outputs as modified are separately combined to provide a plurality of radiation distribution readouts each focused on a different plane in said subject.

4. An apparatus as defined in Claim 3 wherein said image forming and detecting means includes a radiation sensitive material and collimating means for producing said images on said material and wherein said detecting means is moved with respect to the subject thereby moving said images over said material at rates varying with the distance between said detecting means and said sources.

5. An apparatus as defined in Claim 4 wherein said collimating means and said material are connected for joint movement.

6. An apparatus as defined in Claim 2 wherein relative motion between the subject and detecting means cause said images to move over said detecting means at rates which vary with the distance between said detecting means and said sources, and wherein the modifying and combining means comprises display means connected to said detecting means for producing second images corresponding with said first images, a medium for recording said second images, and means providing relative movement between said display means and said recording medium in synchronism with the motion between said subject and said detecting means.

7. An apparatus as defined in Claim 6, and means for adjusting and projecting said second images on said recording medium so that the projected images resulting from radiation sources in said selected plane will move at a like speed and in the same direction as the recording medium.

8. An apparatus as defined in Claim 7, wherein said projection means provides a plurality of adjusted second images each adjusted by a different factor and projected on said recording medium whereby the projections of second images resulting from radiation sources in a plurality of selected planes move at a like speed and in the same direction as the recording medium.

9. An apparatus as defined in Claim 8,

and means changing the orientation of movement of at least one of said projections.

10. An apparatus as defined in Claim 7 wherein said projection means include a plurality of lens means for projecting the second images on separate portions of the recording medium and adjusting the size of the projected images so that in each of said portions the projected images resulting from radiation sources in different planes moves at like speed and direction as the recording medium.

11. An apparatus as defined in Claim 10, and means chaning the orientation of at least one of said projectioned images.

12. An apparatus as defined in Claim 11 wherein said detecting means include converging image producing means and the lens means are selected to obtain a projected second image size D according to the relationship

$$D=2\,\frac{S'}{S}\,(f-b)\,\tan\frac{a}{2}$$

to provide a focused readout of second images caused by radiating sources in said different planes on said portions of the recording medium where

S'=Rate of relative motion between the display means and the corresponding portion of the recording medium,

S=Rate of relative motion between the subject and the image producing means,

D=Diameter of projected second image on the corresponding portion of the recording medium,

f=Distance between the image producing means and the focal plane of the image producing means,

b=Distance from the image producing means to a preselected plane in the subject, and

a=acceptance angle of the image producing means.

13. An apparatus as defined in Claim 1 wherein said modifying and combining means comprises computer means.

14. An apparatus according to Claim 13 wherein the modifying and combining means includes means for changing the magnitude of said first output by at least two different factors to obtain at least two different sets of adjusted outputs wherein said second outputs are signals defining the coordinate position of said detecting means with respect to said subject, and wherein said modifying and combining means adds the coordinate position signals to each of said sets of adjusted outputs to obtain at least two readouts, each readout being focused in a different plane.

15. A method of forming a radioactive radiation distribution readout of radiating sources in a subject comprising:

(a) producing images of said radiation sources on a radiation image detector in such manner that the position of the image of each source varies with the distance between said detector and such source;

(b) producing a first output from said detector defining the position of said images;

(c) examining the subject from more than one position and producing a second output defining the position from which the subject is examined;

(d) modifying at least one of said outputs and containing said outputs as modified to provide a preferential focusing effect on radiating sources located on a selected plane in the subject.

16. A method as defined in Claim 15 including the step of recording the combined outputs of subparagraph (d).

17. A method as defined in Claim 15 wherein said detector moves relative to said subject to move said images over said detector at rates which vary with the distance between said detectors and sources.

18. A method as defined in Claim 17 wherein the step of modifying at least one of the outputs comprises the seps of:

(a) forming second images from said first outputs,

(b) changing the size of said second images,

(c) projecting said second images as changed on a recording medium, and

(d) moving said recording medium in synchronism with said detector at a rate wherein the projection of second images as changed resulting from radiation sources in said selected plane travel at like speed and directions as said recording medium.

19. A method as defined in Claim 18 wherein the step of projecting includes the step of changing the orientation of at least one of said second images.

20. A method as defined in Claim 17 wherein image producing means is disposed adjacent said detector and said step of changing the relaive position is characterized by jointly moving said detector and image producing means.

21. A method as defined in Claim 15 wherein said first and second outputs are characterized by coordinate signals and the step of combining said outputs includes the step of adding said signals.

22. A method as defined in Claim 21 wherein the step of modifying at least one of the outputs comprises the step of modifying the corresponding coordinate signals by constant.

23. A method as defined in Claim 22 for providing radiation distribution readouts of a plurality of selected planes in said subject

wherein one of said coordinate signals is modified by set of constants the value of which vary as a function of the distances between the detector and the selected planes.

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1184304 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

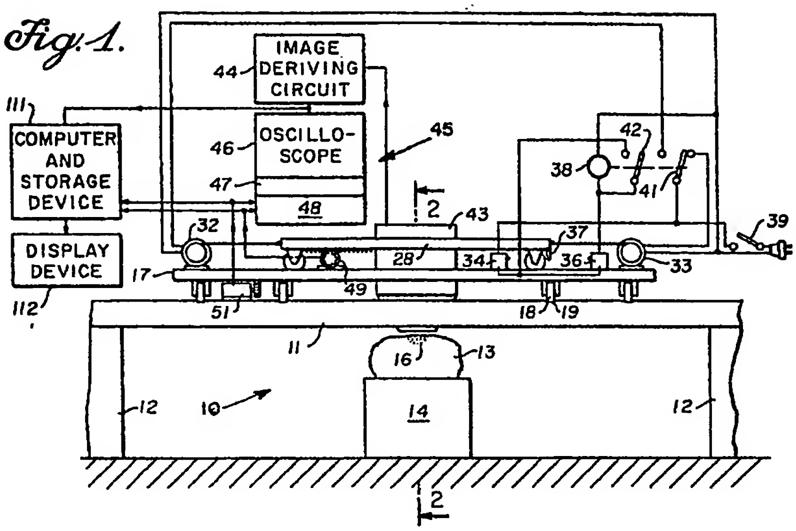


Fig. 1.

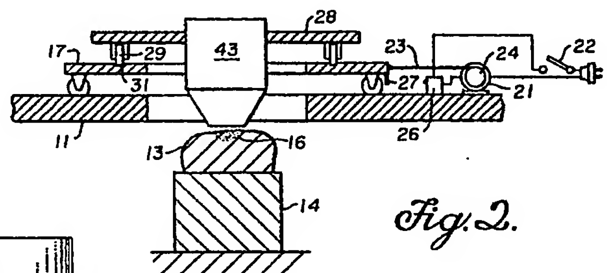


Fig. 2.

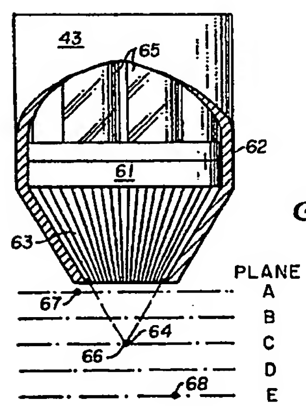
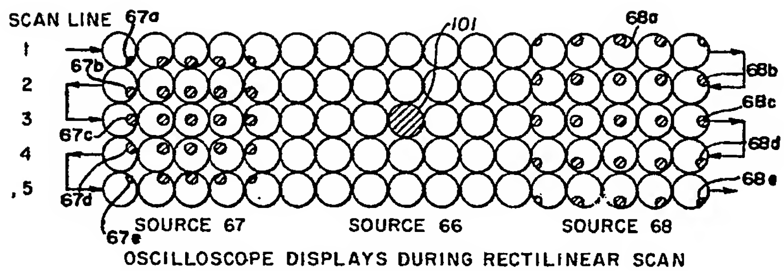


Fig. 3.

1184304 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

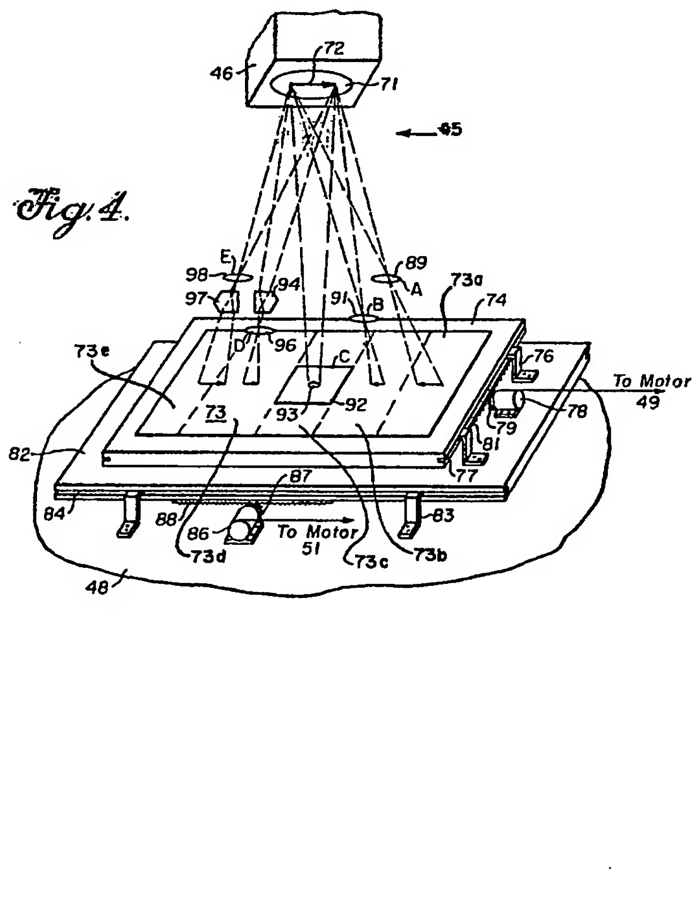
Sheet 2



OSCILLOSCOPE DISPLAYS DURING RECTILINEAR SCAN

Fig. 5.

Fig. 4.



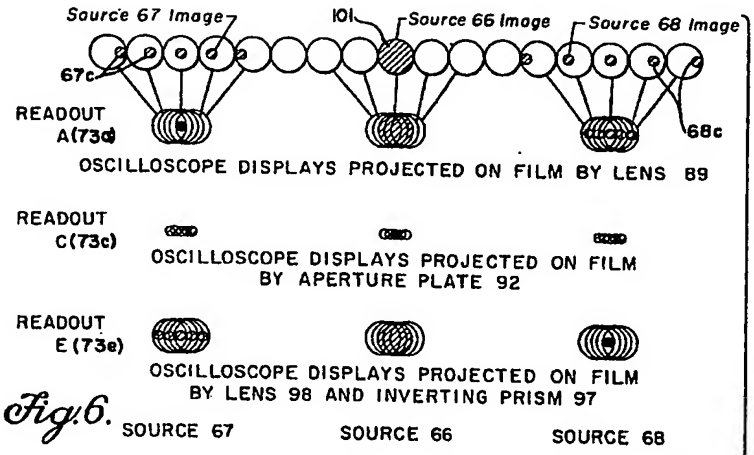

Source 67 Image
101
Source 66 Image
Source 68 Image
67c
68c
READOUT A(73a)
OSCILLOSCOPE DISPLAYS PROJECTED ON FILM BY LENS 89
READOUT C(73c)
OSCILLOSCOPE DISPLAYS PROJECTED ON FILM BY APERTURE PLATE 92
READOUT E(73e)
OSCILLOSCOPE DISPLAYS PROJECTED ON FILM BY LENS 98 AND INVERTING PRISM 97
SOURCE 67
SOURCE 66
SOURCE 68

Fig. 6.

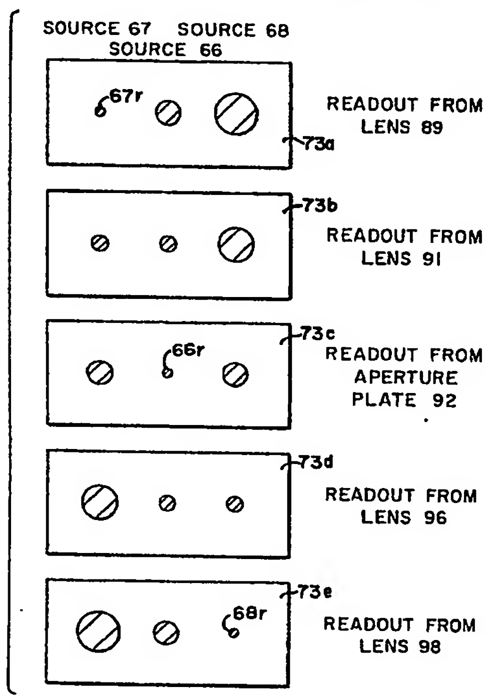

SOURCE 67
SOURCE 68
SOURCE 66
67r
73a
READOUT FROM LENS 89
73b
READOUT FROM LENS 91
73c
66r
READOUT FROM APERTURE PLATE 92
73d
READOUT FROM LENS 96
73e
68r
READOUT FROM LENS 98

Fig. 7.